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WHAT EXPLAINS THE CANADA-U.S. TFP GAP?

Someshwar Rao, Jianmin Tang and Weimin Wang,
Industry Canada

Working Paper 2006-08

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Abstract

Canada's per-capita gross domestic product (GDP) was about 15 percent below the U.S. level in 2005 and the gap has widened slightly in recent years. The Canada-U.S. labour productivity level gap, according to many recent studies, accounted for almost the entire real income gap between the two countries. The gap in capital-labour ratio explained directly about 10 percent of the business sector labour productivity gap in 2004. The remaining 90 percent of the labour productivity gap was due to the gap in total factor productivity (TFP). The objective of this paper, using panel data on 41 industries, is to analyze the factors accounting for the Canada-U.S. TFP gap in the business sector. The regression results show that differences in machinery and equipment (M&E) capital-labour ratio, trade openness and capacity utilization explain well the Canada-U.S. TFP gap across industries over time. The M&E capital intensity gap is the dominant source of the Canada-U.S. TFP gap.

Key words: total factor productivity, the Canada-U.S. productivity gap, capital intensity

Résumé

En 1995, le produit intérieur brut (PIB) par habitant au Canada était inférieur d'environ 15 % à celui des États-Unis, et l'écart s'est légèrement élargi ces dernières années. Selon de nombreuses études récentes, l'écart sur le plan de la productivité du travail entre le Canada et les États-Unis explique presque entièrement l'écart sur le plan du revenu réel entre les deux pays. L'écart au chapitre du ratio capital-travail explique directement environ 10 % de l'écart au chapitre de la productivité du travail du secteur des entreprises en 2004. La proportion restante de l'écart, soit 90 %, est attribuable à l'écart au chapitre de la productivité totale des facteurs (PTF). À l'aide des données recueillies au moyen d'un panel sur 41 industries, les auteurs de la présente étude ont analysé les facteurs responsables de l'écart en matière de PTF entre le Canada et les États-Unis dans le secteur des entreprises. Les résultats de la régression montrent que les différences sur les plans du ratio capital-travail dans les machines et le matériel (M&M), l'ouverture au commerce extérieur et l'utilisation de la capacité expliquent bien l'écart sur le plan de la PTF des industries entre le Canada et les États-Unis, au fil des ans. L'écart sur le plan de l'intensité du capital dans les M&M est principalement à l'origine de l'écart sur le plan de la PTF entre le Canada et les États-Unis.

Mots clés : productivité totale des facteurs, écart de productivité entre le Canada et les États-Unis, intensité de capital

Table of Contents:

1. Introduction

The Canadian economy has performed very well since the mid-1990s in many aspects. Canada has outperformed other G7 countries in real GDP expansion and employment growth. Both inflation and real interest rates are low and stable by historical standards. Canada is the only G7 country with a surplus on both the overall government budget and current accounts. The government debt-GDP ratio has been falling steadily.[1] All these positive trends bode well for the future prosperity of Canada.

Yet, because of Canada's lagging productivity performance, many observers are concerned about the medium-term prospects for Canada's economic growth and improvements in living standards. Labour productivity growth rate in the Canadian business sector averaged a meagre 1.0 percent, over the 2001-2005 period, compared to 2.4 percent during 1995-2000. On the other hand, labour productivity growth in the U.S. business sector accelerated in the post-2000 period, averaging 3.2 percent. Canada's productivity growth has also lagged behind many other OECD countries since 2000.[2]

Although there is a disagreement among researchers about the size of Canada-U.S. labour productivity level gap at the aggregate economy level, there is an agreement among them that Canada's labour productivity level (real GDP per hour) in the business sector is currently well below the U.S. level and the gap has widened in recent years.[3]

Canada is a small and open economy, relying heavily on foreign trade, foreign direct investment, immigration of skilled people and foreign technology flows. In view of intense global and North American competition for these productive resources, closing the Canada-U.S. productivity level gap is vital for narrowing the real income gap as well as for attracting and retaining physical and knowledge capital.

In a previous paper, we examined in some detail the role of capital deepening in the Canada-U.S. labour productivity gap in the business sector (Rao, Tang and Wang (2004)). We concluded that the gap in capital-labour ratio or the gap in capital deepening, accounted for only about 20 percent of the labour productivity gap in the business sector in 2001. The result implied that more than three quarters of the Canada-U.S. business sector labour productivity gap was due to the total factor productivity (TFP) level gap.

The objective of this paper is to analyze the reasons behind the Canada-U.S. TFP level gap in the business sector. Using time-series data (1987-2003) on 41 industries, we examine the factors behind the differences in the TFP gap across industries over time. The regression results suggest that the Canada-U.S. gap in machinery and equipment (M&E), including ICT capital, and differences in trade openness and capacity utilization all explain inter-industry differences in the TFP level gap over time. However, the regression results imply that the M&E gap is the

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[1] For details, see Department of Finance (2005), Conference Board of Canada (2005) and Institute for Competitiveness and Prosperity (2006).

[2] There is no consensus yet about the causes of Canada's post-2000 productivity slowdown (Rao, Sharpe and Smith (2005), Fuss and Waverman (2005) and Ark and Inklaar (2006)).

[3] See Baldwin et al (2005), T.D. Bank (2005), OECD (2005), Rao, Tang and Wang (2004) and Fuss and Waverman (2005).

dominant explanatory variable. Of course, the M&E gap is closely related to the human capital and R&D-intensity gaps.

The paper is organized in the following way. Section 2 provides an overview of the Canada-U.S. labour productivity and TFP gaps, disaggregated by industry. An outline of the empirical model of the TFP gap is provided in section 3. An analysis of trends in explanatory variables is presented in section 4. Regression results are discussed in section 5. The final section, section 6, summarises the key findings of the paper and discusses their implications for policy and future research.

2. Trends in Canada-U.S. Labour Productivity and TFP Gaps

Before we proceed with the discussion of empirical model of the TFP gap and the regression results, it would be useful and informative to examine recent trends in the Canada-U.S. labour productivity and TFP gaps. Using the methodology in one of our earlier papers (Rao, Tang and Wang (2004)), we estimated the labour productivity gap in the business sector for the period 1987-2005 and the TFP gap in the business sector for the period 1987-2004.[4] At the industry level (41 industries), both the labour productivity and TFP gaps are updated for the period 1987-2004.

Unlike our earlier paper, labour input at the industry level is persons employed rather than total hours worked. However, the ideal labour input measure is hours worked. We switched to number of employees in this paper because comparable U.S. hours data at the industry level are not readily available. For our earlier paper (Rao, Tang and Wang (2004)), we obtained hours data from the Jorgenson Project, which developed comparable data for the two countries on labour and other inputs and output for the period 1987-2000.

In this paper, we extend the analysis in Rao, Tang and Wang (2004) up to the year of 2004, using employment data. Since, on average, Canadians work about 10 percent less hours per employed person in a year than their U.S. counterparts, the Canada-U.S. labour and TFP gaps measured in terms of number of employees is about 10 percentage points higher than the gaps measured in terms of hours worked.

Aggregate Trends:

The Canada-U.S. business sector labour productivity gap, using hours worked as labour input, increased from about 16 percent in 1995 to 26 percent in 2005. Much of the widening of the gap occurred after 2000. Similarly, the TFP gap increased from about 19 percent in 1995 to 24 percent in 2004 (Figure 1). The TFP gap is the dominant source of the business sector labour productivity gap. For instance, in 2000, the TFP gap accounted entirely for the business sector

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[4] The term "business sector" used in this paper is defined as NAICS-based all industries excluding education service (NAICS 61), health service (NAICS 62) and public administration (NAICS 91). It should be noted that this definition differs from the Statistics Canada definition of the business sector, which includes the business sector components of education and health services. Unfortunately, data limitations prevented us from adding these sub-industries to the business sector. Since data for the business sector are less subject to measurement error and since international competitiveness is largely shaped by business sector productivity, we concentrate on the business sector productivity level comparisons.

labour productivity gap, compared to 90 percent in 2004. The reduced importance of the TFP gap implies that the widening of the gap in capital deepening between the two countries in the past 10 years was largely responsible for the widening of the business sector labour productivity gap in recent years.

According to our estimates, the deterioration of productivity performance is more serious in the manufacturing sector than in the rest of the economy. The manufacturing sector labour productivity gap, measured in terms of hours worked, steadily increased from a mere 10 percent in 1995 to more than 31 percent in 2004 (Figure 2). Similarly, the TFP level difference deteriorated from a 2 percent advantage in 1995 to a gap of 25 percent in 2004. Once again, the TFP gap was the dominant source of the labour productivity gap in the manufacturing sector in recent years. However, unlike the aggregate business sector, the contribution of TFP gap to the labour productivity gap in the manufacturing sector increased a great deal in the post-1995 period.

As expected, the productivity gap estimates, measured using employees as labour input, are about 10 percentage points higher than the estimates with hours worked as labour input (Figure 3 and Figure 4). For example, in 2004, the business sector labour productivity gap is estimated at 37 percent, compared to 26 percent with data on hours worked. In the manufacturing sector, the estimated labour productivity gap in 2004 was 42 percent, while with hours-worked data, the gap was only 31 percent.

Although there is disagreement among researchers about the size of the Canada-U.S. labour productivity gap at the aggregate economy level, measured using hours-worked data, there is a general consensus about the widening of the productivity gap in the post-1995 period. In addition, all available estimates suggest that the business sector labour productivity gap is fairly large, ranging between 20 and 28 percent for 2005. Since data for the non-business sector are not of reliable quality and long-term international competitiveness is mainly shaped by productivity in the business sector, we concentrate on the business sector.

Industry Dimension:

The industrial disaggregation in this paper is based on NAICS classification system rather than SIC system used in our 2004 paper. As mentioned above, industry level productivity gap estimates in this paper use employment data for labour input. Therefore, the estimates in this paper, where comparable, are higher than the estimates reported in our earlier paper, on average, by about 10 percentage points.

Labour productivity gaps:

There is a great deal of divergence in Canada's productivity level gaps across industries and major sectors, and the differences have increased over time. For instance, in 2004, Canada's labour productivity in the service sector was only 55 percent of the U.S. level, compared to a productivity advantage of over 50 percent in the construction sector (Table 1).

Canada still enjoys a significant (over 6 percentage points) labour productivity advantage over the U.S. in mining, wood, printing, and primary metals. In transportation equipment and paper and paper products industries, Canada's productivity levels are similar to those in the U.S. Nevertheless, they have lost a significant ground to the U.S. since 2000 (Table 1).

On the other hand, in other industries, Canada's productivity levels are considerably below those in the U.S. The productivity disadvantage is really acute (more than 50 percent) in apparel and leather, fabricated metals, computers and electronics, electrical equipment, utilities, information and cultural, professional services and arts and entertainment industries. In all of these industries, Canada lost ground to the U.S. between 1995 and 2003. During this period, in the computer and electronics industry, the Canada/U.S. productivity ratio steadily declined from 1.28 to 0.21 (Table 1). The labour productivity in this Canadian industry grew at 14.5 percent per year during 1995-2000, but declined at 6.8 percent per year during 2000-2004. Meanwhile, the labour productivity of its U.S. counterpart grew much faster, 36.2 percent per year for 1995-2000 and 18.1 percent per year for 2000-2004.

TFP gaps:

The industrial performance of the TFP gap is very similar to that of the labour productivity gap, but the differences across industries are somewhat smaller. Canada also has a TFP advantage in mining, construction, wood, printing, and primary metals. In addition to these industries, Canada's TFP level is higher than that in the U.S. in food, beverage and tobacco, non-metallic minerals, transportation equipment, and other private services (Table 1). On the other hand, Canada's TFP disadvantage in 2004 was large in many service industries, averaging 39 percent for the service sector as a whole (Table 1).

Canada lost significant ground in TFP in 23 industries since 2000, compared to 24 industries for labour productivity. Moreover, in the computers and electronics industry, the loss in TFP advantage is substantive---the Canada-U.S. TFP ratio declined from 1.85 in 1995 to 0.78 in 2000 and to 0.23 in 2004 (Table 1).

In short, the TFP gap is the dominant source of Canada's labour productivity advantage and disadvantage across industries. Therefore, a better understanding of the causes of the TFP gap is critical for developing effective policies for closing the Canada-U.S. productivity gap and improving Canada's international competitiveness.

3. The Model

In this section, we outline the empirical model we used to study the factors behind the TFP gap. The model is based on the production function approach, in which TFP is modelled, rather than assume that it is exogenously given.

We assume that each industry gross output in both Canada and the U.S. is a function of labour, capital, intermediate inputs and TFP or technical progress:

(1) $Q_i = F_i(L_i, K_i, M_i, TFP_i)$, $i = 1, \ldots 41$, for Canada and the U.S.,

where Q_i denotes gross output in constant dollar, and L_i, K_i, and M_i are labour, capital and intermediate inputs, respectively.

Assuming a simple Cobb-Douglas functional form for equation (1), constant returns to scale and separability of intermediate inputs from primary inputs (labour and capital), we can write equation (1) in terms of value-added:

(2) $V_i = Q_i - M_i = G_i(L_i, K_i, TFP_i)$, $i = 1,\ldots 41$.

Equation (2) can be expressed in terms of value-added labour productivity:

(3) $V_i / L_i = H_i(K_i / L_i, TFP_i)$, $i = 1,\ldots 41$.

Value-added labour productivity is a function of capital-labour ratio (capital deepening) and TFP. Under the assumption of the Cobb-Douglas functional form for the value-added production function and constant returns to scale, equation (3) can be re-written in log form as:

(4) $\ln(y_i) = a_i * \ln(k_i) + \ln(TFP_i)$, $i = 1,\ldots 41$,

where y_i is value-added labour productivity, k_i is the capital-labour ratio, TFP_i is total factor productivity or technical progress, and a_i is the elasticity of output with respect to capital input.

According to equation (4), value-added labour productivity growth will be equal to the contribution of capital deepening (changes in the capital-labour ratio) plus TFP growth.

In this paper, we will model the variation in TFP gap across industries over time. To accomplish this goal, we assume that TFP in each industry responds to changes in M&E capital (including ICT capital), human capital or skills, R&D, trade openness and capacity utilization (business cycle):

(5) $TFP_i = J_i(m_i, s_i, r_i, o_i, b_i)$, $i = 1,\ldots, 41$,

where m_i is the M&E capital-labour ratio, s_i is the percentage of employees with a university degree, a proxy for skills or labour quality, r_i is the R&D-GDP ratio, o_i is the ratio of exports and imports in value added, and b_i is capacity utilization (business cycle). ICT capital is part of the M&E capital.

Equation (5) implicitly assumes that TFP in the longer-term is influenced by both fundamental and applied innovation. R&D and human capital are assumed to be the main drivers of fundamental innovation. Applied innovation or adoption and diffusion of new and the state-of-art technologies are expected to be influenced largely by M&E capital and human capital. Of course, all three variables are interrelated. Therefore, it is difficult to empirically disentangle precisely their separate impact on TFP (see Harris (2002) and Rao, Tang and Wang (2004) for a detailed discussion on the importance of these three variables for productivity). Changes in capacity utilization also impact productivity in the short-term, because of delays in fully adjusting inputs and outputs to changes in relative prices, technologies and business cycles.

Past theoretical and empirical research suggest that trade openness is also an important determinant of TFP, because of its positive impact on competition, economies of scale and specialization, and technology and knowledge transfer. To capture the impact of differences in trade openness on productivity, we added the ratio of exports and imports to value added as a separate explanatory variable in equation (5).

Recent research suggests that ICT capital contributes significantly both directly and indirectly to labour productivity growth in Canada and other OECD countries.[5] They contribute directly through capital accumulation and capital deepening. They also could contribute indirectly through their significant positive impact on organisational and applied innovation and network effects, often referred as spillovers or externalities. In an effort to check if ICT capital impacts TFP differently from non-ICT M&E capital, we included the ratio of ICT capital to total M&E capital as an additional explanatory variable in the TFP equation:

$$\textbf{(6)} \qquad TFP_i = J_i(m_i, s_i, r_i, o_i, b_i, z_i), \quad i = 1, \ldots, 41,$$

where z_i is the ratio of ICT capital to total M&E capital. For the purposes of this paper, we modify equation (6) in the following manner:

$$\textbf{(7)} \qquad \frac{TFP_i^{CA}}{TFP_i^{US}} = N_i\left(\frac{m_i^{CA}}{m_i^{US}}, \frac{s_i^{CA}}{s_i^{US}}, \frac{r_i^{CA}}{r_i^{US}}, \frac{o_i^{CA}}{o_i^{US}}, \frac{z_i^{CA}}{z_i^{US}}, b_i^{CA} - b_i^{US}\right), \quad i = 1, \ldots, 41.$$

Equation (7) expresses the Canada-U.S.TFP ratio or the TFP gap as a function of the M&E capital intensity gap, skills gap, R&D intensity gap, the ratio of trade openness in the two countries, the ratio of ICT capital share in Canada to the U.S share and differences in capacity utilization in the two countries. Using the time-series data on 41 industries, we estimated the parameters of equation (7).

4. A Discussion of Explanatory Variables

In this section, we examine recent trends in explanatory variables, disaggregated by industry. This analysis will be very helpful to the reader for appreciating better the regression results. Definitions of variables and data sources are given in Annex A.

M&E capital gap:

In 2004, in all four major sectors of the economy, the M&E capital/labour ratio in Canada was considerably below the U.S. level. The M&E capital intensity gap varied from a low of 21 percent in construction to over 50 percent in the service sector. In the manufacturing sector, the M&E capital intensity gap widened a great deal since 1995. It increased steadily from 26 percent in 1995 to 46 percent in 2004 (Table 2).

Within the manufacturing sector, with the exception of wood and paper industries, the M&E capital intensity is well below the U.S. level in all of Canadian industries. In 2004, the M&E capital gap varied from a low of 16 percent in transportation equipment industry to a high of 86

[5] See Pilat (2005), Fuss and Waverman (2005), Jorgenson (2004), and Rao and Tang (2004).

percent in machinery industry (Table 2). In paper and wood industries, Canada's M&E capital advantage declined dramatically (between 23 and 26 percentage points) in the last 10 years.

The M&E capital intensity gap is considerably below the U.S. level in all service industries in Canada. In 2004, the gap varied from a low of 34 percent in information and cultural service industry to over 83 percent in accommodation and food (Table 2).

Importance of ICTs in M&E capital:

The ICT capital share in the Canadian business sector increased from 15.6 percent in 1995 to 20.0 percent in 2003. In addition, its share in M&E capital increased in three of the four major Canadian sectors since 1995. But, the importance of ICT capital varies a great deal across major sectors. The ICT capital share averaged about 31 percent in the service sector in 2003, while it averaged less than 5 percent in other three sectors (Table 3).

The share of ICT capital is bigger and increased faster since 1995 in the U.S. than in Canada in three of the four major sectors, while it is slightly smaller in the service sector.

In all Canadian manufacturing industries, the share of ICTs in M&E capital was below 10 percent in 2003, except in computers and electronics. In addition, the ICT capital share is significantly bigger in most of the U.S. manufacturing industries than their Canadian counterparts. Furthermore, in 2004, the ICT capital share in six U.S. manufacturing industries was above 10 percent, compared to only two industries in Canada. The ICT capital share averaged 11.6 percent in the U.S. manufacturing sector, compared to only 3.9 percent in Canada (Table 3).

Unlike manufacturing, the ICT capital share is significantly bigger in all Canadian service industries than in the U.S., except in transportation and warehousing and finance, insurance and real estate. But, at the aggregate service sector, there is no difference between the two countries. It averaged 32 percent in 2003 in both countries (Table 3).

R&D-intensity gap:

In 2003, Canada's R&D/GDP ratio in the Canadian business sector was only 54 percent of the U.S. level. In addition, the R&D intensity was less than 10 percent of the U.S. level in the primary sector, compared to 59 percent in the manufacturing sector. The R&D gap at the aggregate business sector level remained more or less constant since 1995. On the other hand, the R&D-intensity gap in the manufacturing sector declined from 52 percent in 1995 to 41 percent in 2003 (Table 4).

There is a wide variation in the R&D-intensity gap across manufacturing industries in 2003. Canada's R&D-intensity is well above the U.S. level in textiles, primary metals and computers, and electronics industries. On the other hand, the gap is above 80 percent in printing, plastics and rubber, and non-metallic minerals (Table 4). In eight of the 18 manufacturing industries, the R&D gap narrowed significantly since 1995, while the gap widened in the remaining industries. In the transportation equipment industry, the gap declined from 80 percent in 1995 to 65 percent

in 2003. On the other hand, in the electrical equipment industry, the R&D gap increased by 34 percentage points, reaching 63 percent in 2003. Like manufacturing, there is also considerable divergence in the R&D-intensity gap across service industries. Canada's R&D intensity is well above the U.S. level in professional services, while the gap is over 90 percent in transportation and warehousing.

Skills gap:

As in Rao, Tang and Wang (2002), the share of hours with university education in total hours is used as a proxy for skills-intensity or labour quality in this paper. Canada also lags behind the U.S. in terms of skills-intensity. In 2000, the skills gap between Canada and the U.S. was 32 percent in the business sector, although the gap narrowed somewhat since 1995. In all the four major sectors, there is a large skills gap, varying from a low of 28 percent in the service sector to a high of 45 percent in the manufacturing sector (Table 4).

Canada's skills-intensity is significantly below the U.S. level in all of the manufacturing industries. The skills gap is over 52 percent in electrical equipment and transportation equipment (Table 4). Within the service sector, Canada has a considerable skills advantage in professional and administrative services. On the other hand, the skills gap is over 57 percent in transportation and warehousing.

Trade openness:

As expected, trade openness (ratio of exports and imports to value added) is considerably bigger in the Canadian manufacturing sector than in the U.S., 3.3 vs. 1.3. Similarly, in the primary sector also Canada leads the U.S. by a significant margin. Nevertheless, trade openness declined significantly in Canada between 2000 and 2003 in the manufacturing sector, while it increased in the U.S., leading to a narrowing of Canada's advantage (Table 5). We could not obtain data on trade openness variable for construction and service industries for Canada as well as the U.S. For these industries, we assumed the ratio of Canada's trade openness to the U.S. openness to be one in our regression analysis.

Within the manufacturing sector, trade openness varies a great deal across individual industries in both Canada and the U.S. In 2003, the ratio in Canada varied from a low of 0.5 in printing to 9.7 in computer equipment and electronics. For the U.S., trade openness ratio varied between 0.2 and 5.4 (Table 5). Canada's trade openness ratio exceeded the U.S. ratio in all manufacturing industries (except apparel and leather). In 11 of 18 Canadian manufacturing industries, trade openness fell between 2000 and 2003. In contrast, trade openness declined in only two U.S. manufacturing industries.

In summary, Canada generally lags behind the U.S. in M&E capital, skills and R&D intensity. Nevertheless, Canada has an advantage in some individual industries in all three areas. The share of ICT capital in total M&E capital is more or less same at the aggregate business sector level in the two countries. Canada leads the U.S. in trade openness, but the advantage narrowed significantly since 2000.

5. Regression Results

Using the time-series data (1987-2003) on 41 industries, we ran a number of regressions of the above Equation (7).[6] For the sake of analytical convenience, we have reported in Table 6 only three regression equations.[7]

All three regressions control for industry fixed effects. They explain about 90 percent of inter-industry variations in TFP gap over time. As expected, the coefficients on M&E capital intensity, share of university hours and R&D intensity, trade openness and capacity utilization (the proxy for business cycle) are positive (column 1, Table 6).

The coefficient on the M&E capital gap is highly significant, and the size of the coefficient is fairly robust across various alternative specifications of Equation (7) (Annex B and Table 8). The coefficient on the M&E capital intensity implies that a one percent increase in the M&E capital intensity gap would raise the TFP gap by about 0.13 percent, and vice versa. This result implies that M&E capital (including ICT capital), by embodying new technologies, would stimulate applied innovation and technology transfer, and raise TFP. Hence, a reduction in the M&E capital gap would reduce the labour productivity gap directly via the capital deepening impact as well as indirectly by reducing the TFP gap.

The coefficient on trade openness has the expected positive sign and is significant in all the three regressions. As expected, the coefficient on capacity utilization (business cycle) is positive and highly statistically significant. Hence, it is important to control for the influence of the short-term differences in business cycles in the two countries on the Canada-U.S. TFP gap. Of course, the longer-term impact of this variable on the TFP gap is expected to be very small.

However, the coefficients on share of university hours and R&D intensity are not statistically significant. The lack of significance of the coefficients on share of university hours and R&D intensity could be due to high correlation between the skills, R&D and M&E capital.[8] Therefore, it is difficult to disentangle accurately the influence of each of the three variables on the TFP gap. In the regressions without M&E capital intensity, R&D intensity becomes significant (columns (2) and (3), Table 6)

Contrary to expectations, the coefficient on the Canada-U.S. gap in the share of ICT capital in M&E capital is negative and statistically significant. The negative coefficient on the ICT share variable, however, does not imply that a reduction in ICT capital gap increases the TFP gap. On

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[6] The sample is only up to 2003 since we only have data up to 2003 for most of the explanatory variables.

[7] The estimation method we use is period SUR with panel-corrected standard errors (PCSE) (Beck and Katz (1995)). The associated covariance structures allow for arbitrary period serial correlation and period heteroskedasticity between the residuals for a given cross-section, but restricted residuals in different cross-sections to be uncorrelated. The advantage of this estimation method is that it can take care of period heteroskedasticity and serial correlation without using the lagged dependent variable. In Annex B we present alternative estimation results using FGLS with cross-section weights to take care of cross-sectional heteroskedasticity.

[8] The findings in Rao, Tang and Wang (2006) support a complementary relationship between M&E capital, skills and R&D. Note also that we only have data up to 2000 for the skill variable and assume the Canada-U.S. relative level has been unchanged since 2000. This assumption might impact the estimation results.

the contrary, our regression results suggest that the ICT capital gap is as important as the non-ICT M&E capital gap for the TFP gap, but it does not have an additional impact on the productivity gap. For instance, when we replace the M&E capital gap with the ICT capital gap (column 2), the coefficient on the ICT capital gap is positive and statistically significant. But, the size of the ICT capital gap variable is considerably smaller than the coefficient on the M&E capital gap (column 1), and the explanatory power of equation is weaker than the equation with the M&E capital gap. Our results that ICT capital does not seem to play a special role in explaining inter-industry differences in the Canada-U.S. TFP gap is broadly consistent with the findings of other researchers about the absence of productivity spillovers from ICTs (see Stiroh (2002), Bosworth and Triplett (2004) and Harchaoui and Tarkhani (2005)).

In short, our regression results suggest that the differences in ICT capital shares in the two countries did not contribute to the TFP gap. Nevertheless, these are important findings. We intend to check for the robustness of these results with further in-depth research on the impact of ICTs on TFP in Canadian and U.S. industries.

In summary, the M&E capital gap (including ICT capital gap), the skills gap and the R&D gap, trade openness gap all contributed to the TFP gap. But, the regression coefficients imply that the M&E capital gap alone was responsible for over 90 percent of the business sector TFP gap in 2003, computed at the sample mean. The gaps in skills and R&D contributed about 5 percent to the gap (Table 7).

It is important to note that, however, given a high degree of correlation and complementarity among the M&E, skills and R&D, these decomposition results should be used with caution. But, it is clear from the regression results that the M&E capital gap is the dominant source of the TFP gap.

6. Conclusions

The main objective of this paper has been to examine inter-industry variations in Canada-U.S. TFP gap over time and analyse main reasons for the TFP level gap. Towards this objective, using comparable time-series data for the period 1987-2003 on 41 Canadian and U.S industries, first, we estimated the TFP gaps by industry. Next, we developed and estimated an empirical model of the TFP gap.

The following are the key findings:

- The Canada-U.S. TFP gap in the business sector, measured using hours as labour input, increased from 19 percent in 1995 to 24 percent in 2004;

- The TFP gap accounted for 90 percent of the business sector labour productivity gap in 2004, but its contribution declined significantly since 1995;

- Employee- based labour productivity and TFP gaps in general are about 10 to 12 percentage points larger than hours-based gap estimates, because Canadians on average work about 10 percent less hours per year than their U.S. counterparts;

- Canada has a significant productivity advantage over the U.S. in mining, resource-based manufacturing industries and construction. On the other hand, the productivity gap is large in service industries and high-tech manufacturing industries, especially in computers and electronics;

- The regression results suggest that the M&E capital intensity gap, trade openness and capacity utilization have all contributed to the Canada-U.S. TFP gap. The estimated coefficients, however, imply that the M&E capital intensity gap was the dominant source of the TFP gap. Of course, given that the gaps in M&E capital intensity, R&D intensity and skills are interrelated and complement one another, it is difficult to separate out neatly the effect of each of the gaps on the TFP gap.

Our results imply that closing the M&E capital intensity gap is crucial for closing the labour productivity and real income gaps with the U.S. A reduction in the M&E capital intensity gap reduces the labour productivity gap directly via the capital deepening effect, and indirectly by stimulating applied innovation (adoption and diffusion of new technologies), and reduces the TFP gap. In addition, an increase in M&E capital would also increase investments in skills and R&D, because of complementarity between the three variables.

Recent research suggests that ICT capital imparts significant positive productivity spillovers because ICTs are general-purpose technologies[9]. However, our empirical results imply that the TFP impact of ICT capital is the same as that of non-ICT M&E capital. Given the importance of estimates of spillovers for policy discussions, a more in-depth empirical analysis of the impact of ICT capital on TFP in Canadian and U.S. industries would be very useful.

The results of this study point to the importance of improving the conditions for investment in M&E, which often leads to the adoption of new technologies. Investment spending has increased substantially over the past two years, reflecting in part the decline in investment prices associated with the appreciation of the Canadian dollar. This should help improve Canada's productivity performance. Moreover, a slowdown in labour force growth, associated with ageing of the population, will likely lead to further capital deepening as the relative price of capital to labour falls. Other factors that would be important for improving Canada's productivity performance are smart regulation, a competitive and efficient tax system, and openness to internal and international trade and investment.

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[9] Fuss and Waverman (2005) argue that the ICT capital gap accounted for 55% of the Canada-U.S. productivity gap in 2003 because of the huge network (spillover) effects.

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Annex A: Variable Definitions and Data Sources

Capital Intensity

Capital intensity is defined as capital stock per worker. The capital stock used is the private fixed non-residential geometric end-year net stock. Three types of capital intensities are used in the paper, i.e., total capital[10] intensity, M&E capital intensity and ICT capital intensity. To calculate Canada-U.S. capital intensity level gap, capital stock in Canadian dollar for Canada is converted into US dollar using the Canada-U.S. bilateral total investment PPP values by industry for total capital stock and M&E investment PPP values by industry for M&E and ICT capital stock. All the PPP values are obtained from Rao, Tang and Wang (2004). All capital stock series are in chained-Fisher dollar and re-referenced to the year of 1999.

The Canadian data for total capital stock and M&E capital stock by industry are obtained from Statistics Canada (STC) CANSIM table 031-0002, and the Canadian data for ICT capital stock come from the Investment and Capital Stock Division of Statistics Canada. All capital stock data for the U.S. come from the U.S. Bureau of Economic Analysis (BEA) fixed assets tables.

The data used for Canadian employment from 1997 onward is the total number of jobs from STC CANSIM table 383-0010. These data are extended back to 1987 using the growth rates of the total number of jobs from STC CANSIM table 383-0003. The employment data for the U.S. is the number of persons engaged in production. The source for the data from 1998 onward is the BEA NAICS-based GDP-by-industry tables, which are extended back to 1987 using the growth rates of the number of persons engaged in production from the BEA1987 SIC-based GDP-by-industry tables.

Total-Factor Productivity (TFP)

Canada-U.S. TFP gap is estimated using $\ln\left(TFP^{CA}/TFP^{US}\right) = \ln\left(LP^{CA}/LP^{US}\right) - \overline{w}\ln\left(k^{CA}/k^{US}\right)$, where LP is GDP at factor cost per worker, k is capital intensity, and $\overline{w}$ is the average capital share of income of the two countries.

GDP at factor cost in 1999 for Canada is obtained from STC CANSIM table 381-0013 and converted into US dollar using the Canada-U.S. bilateral GDP PPP values by industry from Rao, Tang and Wang (2004). The imputed value for owner-occupied dwellings is not included. The time series of GDP at factor cost in 1999 dollar are estimated using the growth rates of GDP at basic price in 1997 chained-Fisher dollar. The GDP at basic price in 1997 chained-Fisher dollar from 1997 onward come from STC CANSIM table 379-0017, which are extended back to 1987 using the growth rates of GDP at factor cost in 1992 constant dollar from STC CANSIM table 379-0001. The capital share of income is calculated using the data from STC CANSIM table 381-0013.

GDP at factor cost in 1999 for the U.S. is calculated using the data from BEA NAICS-based GDP-by-industry tables. The imputed value for owner-occupied dwellings is excluded using

[10] Total capital includes structure and M&E capital. Land and inventory are not included.

BEA NIPA table 7-12. The time series of GDP at factor cost in 1999 dollar are estimated using the chained-Fisher quantity index for GDP at market price from BEA NAICS-based GDP-by-industry tables. The capital share of income is calculated using the same source tables.

Skills

The share of hours worked by workers with university degree and above in total hours worked is used as the indicator of skills. The data of hours worked by industry and by education for both Canada and the U.S. for the period of 1987 to 2000 are obtained from Jorgenson (2004). The shares are assumed to be unchanged since 2000.

R&D Intensity

R&D intensity is defined as R&D expenditure to GDP ratio. The R&D expenditure data used for Canada is the intramural R&D expenditures that are obtained from the Science, Innovation and Electronic Information Division of Statistics Canada. The data from 1994 onward is NAICS-based. It is extended back to 1987 using the growth rates from the SIC-based data. The R&D data used for the U.S. is the total funds for industrial R&D performance. The sources of the data for non-agriculture industries are Table A-7 and Table A-13, Survey of Industrial Research and Development, 1998, 2000, 2001, the U.S. National Science Foundation. NAICS-based data are available for the period of 1997 to 2001 and SIC-based data are available for the period of 1988-1998. The growth rates from SIC-based data are used to extend NAICS-based data back to 1988. The data for 1987 are assumed to be the same as those for 1988, and the data for 2002 and 2003 are assumed to be the same as those for 2001. The data for the agriculture sector are obtained from the U.S. Department of Agriculture.

Trade Openness

Trade Openness is defined in this paper as total merchandise trade (exports plus imports) to GDP (at factor cost) ratio. The trade data for Canada are NAICS based after 1992 and SIC based before 1992, and the trade data for the U.S. are NAICS based after 1997 and SIC based before 1997. The NAICS-based trade openness for both Canada and the U.S. are extended back to 1987 using the growth rates of the SIC-based trade openness. The NAICS-based trade data for Canada are obtained from Industry Canada Trade-on-line database, and the SIC based trade data are from Statistics Canada. The sources for Canadian GDP at factor cost are STC CANSIM table 381-0013 for NAICS-based data and CANSIM table 379-0001 for SIC-based data. The U.S. trade data are obtained from the U.S. International Trade Commission Trade Data Web, and the U.S. GDP at factor cost are obtained from the U.S. BEA GDP-by-Industry tables.

Capacity Utilization

The output fluctuation is used as the indicator of capacity utilization because firms will adjust factor inputs accordingly in response to output change. The data used for output is real GDP by industry. The Hodrick-Prescott (H-P) filter is used to decompose GDP into two parts: the long-term trend and the short-term fluctuation. For normalization, the fluctuation is divided by the trend.

Annex B: Alternative Estimation Results

The estimation results in Table 6 are obtained using period SUR with PCSEs. The associated covariance structures allow for arbitrary period serial correlation and period heteroskedasticity between the residuals for a given cross-section, but restricted residuals in different cross-sections to be uncorrelated.

To check the robustness of the estimation results in Table 6, we re-estimate the impact of the same independent variables on the Canada-U.S. relative TFP level using reduced-form error-correction model (ECM). The feasible GLS (cross-section weights) with PCSEs is used to estimate the model. The ECM can be written as

(B1) $$\Delta y_t = \alpha + (\beta - 1)(y_{t-1} - \lambda X_{t-1}) + \gamma_0 \Delta X_t + \varepsilon_t.$$

The error-correction term is $(\beta - 1)(y_{t-1} - \lambda X_{t-1})$, where λ stands for the long-run impact of X on y. Equation (B1) can be re-written after a rearrangement of parameters as

(B2) $$y_t = \alpha + \beta y_{t-1} + \gamma_0 X_t + \gamma_1 X_{t-1} + \varepsilon_t, \text{ with } \lambda \equiv \frac{\gamma_0 + \gamma_1}{1 - \beta}.$$

Equation (B2) is an ADL(1,1) model. It is linear and easy to be estimated. The FGLS estimation results with cross-section weights (CSW) of Equation (B2) using the same group of variables as in equation (7) are presented in Table 8. As shown in the table, the impact of M&E capital on TFP is positive and statistically significant. The CSW estimation of the long-run elasticity of the Canada-U.S. relative TFP level to the relative M&E capital intensity is 0.19, which is larger than the SUR estimation of 0.13 (Table 6). The CSW estimation of the impact of skills is quite dramatic; the corresponding long-run elasticity is 0.54. In contrast, the SUR estimation for the impact of skills is close to zero. The impact of R&D is numerically very small in both sets of estimations. The long-run elasticity for ICT share in M&E capital is negative but very small (-0.01) in CSW estimation. The long-run elasticity for trade openness is 0.1 in CSW estimation and 0.06 in SUR estimation, implying than the trade openness has limited impact on the relative TFP level. Generally speaking, the two sets of estimations give more or less the same results for all independent variables considered except skills.

Tables and Charts

Table 1: Canada's Labour Productivity and TFP Levels Relative to the U.S. by Industry (U.S.=1)

Industry	NAICS Code	GDP per worker			TFP		
		1995	2000	2004	1995	2000	2004
Primary		**0.81**	**0.83**	**0.98**	**0.84**	**0.74**	**0.76**
Agriculture	11	0.55	0.50	0.54	0.74	0.65	0.68
Mining	21	1.09	1.16	1.42	1.09	1.02	1.13
Construction	23	**1.07**	**1.32**	**1.50**	**1.07**	**1.35**	**1.55**
Manufacturing		**0.88**	**0.74**	**0.58**	**0.93**	**0.77**	**0.66**
Food, beverage, tobacco	311, 312	0.65	0.75	0.77	0.90	1.02	1.04
Textile	313, 314	0.76	0.74	0.54	0.79	0.84	0.66
Apparel and leather	315, 316	0.66	0.56	0.38	0.72	0.78	0.55
Wood	321	0.89	1.08	1.16	0.82	1.00	1.09
Paper	322	1.01	1.13	0.97	0.86	0.99	0.93
Printing	323	0.98	1.02	1.06	1.15	1.29	1.41
Petroleum and coal	324	1.06	0.63	0.80	0.98	0.67	0.80
Chemical	325	0.79	0.88	0.81	0.89	0.97	0.95
Plastics and rubber	326	0.63	0.57	0.50	0.73	0.73	0.69
Non metallic	327	0.89	0.93	0.89	0.95	1.06	1.09
Primary metals	331	1.16	1.22	1.12	1.20	1.23	1.18
Fabricated metal	332	0.50	0.49	0.47	0.64	0.69	0.68
Machinery	333	0.64	0.64	0.58	0.86	0.99	0.91
Computer and electronic	334	1.28	0.54	0.21	1.85	0.78	0.23
Electrical equipment	335	0.45	0.59	0.40	0.64	0.83	0.57
Transportation equipment	336	1.08	1.23	1.00	1.07	1.28	1.08
Furniture	337	0.66	0.71	0.67	0.70	0.83	0.81
Miscellaneous manufacturing	339	0.61	0.44	0.38	0.90	0.73	0.70
Services		**0.62**	**0.61**	**0.55**	**0.65**	**0.65**	**0.61**
Utilities	22	0.69	0.65	0.49	0.63	0.60	0.53
Wholesale trade	41	0.77	0.74	0.62	1.07	1.00	0.90
Retail trade	45 (or 44)	0.64	0.70	0.60	0.79	0.83	0.73
Transportation, Warehousing	48-49	0.83	0.85	0.81	0.88	0.88	0.84
Information and cultural	51	0.73	0.60	0.47	0.79	0.68	0.58
FIRE, management	52, 53, 55	0.62	0.60	0.59	0.65	0.66	0.67
Professional services	54	0.49	0.49	0.46	0.69	0.59	0.58
Administrative services	56	0.83	0.75	0.68	1.09	0.99	0.95
Arts, entertainment	71	0.52	0.51	0.49	0.64	0.64	0.63
Accommodation and food	72	0.85	0.79	0.70	0.97	0.93	0.85
Other private services	81	0.69	0.91	1.02	0.95	1.18	1.29
Total Business		**0.72**	**0.70**	**0.63**	**0.72**	**0.71**	**0.66**

Source: Authors' calculations based on data from Statistics Canada and the U.S. BEA.

Table 2: Canada's M&E Capital Intensity Level Relative to the U.S. by Industry (U.S.=1)

Industry	NAICS Code	M&E Capital Intensity		
		1995	2000	2004
Primary		**0.30**	**0.37**	**0.52**
Agriculture	11	0.35	0.34	0.34
Mining	21	0.24	0.35	0.52
Construction	23	**1.07**	**0.81**	**0.79**
Manufacturing		**0.74**	**0.62**	**0.54**
Food, beverage, tobacco	311, 312	0.44	0.46	0.49
Textile	313, 314	0.71	0.57	0.43
Apparel and leather	315, 316	0.61	0.33	0.23
Wood	321	1.53	1.38	1.27
Paper	322	1.25	1.21	1.02
Printing	323	0.50	0.45	0.39
Petroleum and coal	324	0.24	0.21	0.47
Chemical	325	0.64	0.66	0.57
Plastics and rubber	326	0.57	0.49	0.43
Non metallic	327	0.78	0.70	0.62
Primary metals	331	0.80	0.91	0.79
Fabricated metal	332	0.31	0.28	0.24
Machinery	333	0.23	0.17	0.14
Computer and electronic	334	0.24	0.28	0.24
Electrical equipment	335	0.28	0.39	0.35
Transportation equipment	336	1.12	0.91	0.84
Furniture	337	0.51	0.46	0.41
Miscellaneous manufacturing	339	0.22	0.19	0.18
Services		**0.51**	**0.52**	**0.49**
Utilities	22	0.75	0.77	0.63
Wholesale trade	41	0.15	0.19	0.17
Retail trade	45 (or 44)	0.39	0.50	0.51
Transportation, Warehousing	48-49	0.35	0.41	0.44
Information and cultural	51	0.79	0.66	0.66
FIRE, management	52, 53, 55	0.55	0.59	0.59
Professional services	54	0.44	0.49	0.34
Administrative services	56	0.36	0.24	0.21
Arts, entertainment	71	0.14	0.15	0.15
Accommodation and food	72	0.12	0.10	0.07
Other private services	81	0.14	0.26	0.36
Total Business		**0.60**	**0.59**	**0.56**

Source: Authors' calculations based on data from Statistics Canada and the U.S. BEA.

Table 3: Share of ICT Capital in Total M&E Capital (%)

Industry	NAICS Code	Canada			U.S.		
		1995	2000	2003	1995	2000	2003
Primary		**1.46**	**1.85**	**1.69**	**2.72**	**2.94**	**2.91**
Agriculture	11	1.18	1.56	1.97	0.98	1.02	1.04
Mining	21	1.96	2.15	1.50	5.16	5.79	5.95
Construction	23	**4.83**	**4.39**	**4.78**	**8.71**	**13.45**	**13.14**
Manufacturing		**2.82**	**3.61**	**3.90**	**7.99**	**10.81**	**11.60**
Food, beverage, tobacco	311, 312	3.96	5.11	4.83	4.93	6.32	6.42
Textile	313, 314	1.83	2.67	2.70	3.26	3.60	3.70
Apparel and leather	315, 316	5.01	6.82	6.21	5.78	6.99	7.82
Wood	321	2.16	2.11	2.26	4.53	4.84	5.17
Paper	322	1.59	2.02	2.46	3.05	3.98	4.29
Printing	323	6.05	6.24	6.10	5.42	8.02	8.36
Petroleum and coal	324	4.17	3.40	4.60	4.11	4.76	5.00
Chemical	325	3.04	3.29	4.04	9.41	12.83	13.17
Plastics and rubber	326	3.87	3.51	3.38	2.37	3.45	3.61
Non metallic	327	1.77	3.67	3.96	5.37	6.63	6.89
Primary metals	331	1.98	2.66	2.74	3.61	3.81	3.96
Fabricated metal	332	2.46	3.02	3.28	5.28	6.25	6.63
Machinery	333	5.29	6.55	6.88	12.97	17.91	18.90
Computer and electronic	334	6.88	15.25	14.53	18.02	20.97	24.43
Electrical equipment	335	6.35	6.44	5.75	10.78	10.36	11.70
Transportation equipment	336	3.43	3.42	4.15	12.32	15.69	15.40
Furniture	337	3.90	6.48	5.65	6.64	7.37	7.07
Miscellaneous manufacturing	339	6.06	10.71	8.13	10.37	11.78	12.36
Services		**25.87**	**30.51**	**31.51**	**24.75**	**30.86**	**31.64**
Utilities	22	2.98	6.22	7.34	6.59	6.69	6.73
Wholesale trade	41	25.53	37.72	40.47	19.08	20.52	20.30
Retail trade	45 (or 44)	17.97	19.75	20.65	17.30	18.16	18.16
Transportation, Warehousing	48-49	3.39	8.49	8.17	13.58	24.13	28.13
Information and cultural	51	95.87	97.08	98.97	66.60	74.33	85.82
FIRE, management	52, 53, 55	21.91	21.38	21.85	24.89	25.01	23.42
Professional services	54	79.03	64.95	68.62	45.42	63.21	60.43
Administrative services	56	45.62	54.44	55.64	23.27	31.90	30.85
Arts, entertainment	71	19.39	45.63	45.13	8.98	10.37	10.60
Accommodation and food	72	6.38	6.65	6.88	5.20	5.48	5.02
Other private services	81	37.02	39.06	39.68	12.74	15.26	16.27
Total Business		**15.63**	**18.80**	**19.98**	**17.70**	**23.02**	**24.03**

Source: Authors' calculations based on data from Statistics Canada and the U.S. BEA.

Table 4: Canada's Skills and R&D Intensity Levels Relative to the U.S. by Industry (U.S.=1)

Industry	NAICS Code	Share of University Hours*		R&D to GDP Ratio**		
		1995	2000	1995	2000	2003
Primary		**0.41**	**0.64**	**0.13**	**0.09**	**0.09**
Agriculture	11	0.34	0.54	0.04	0.05	0.05
Mining	21	0.57	0.73	4.82	0.52	0.48
Construction	23	**0.52**	**0.59**	**2.90**	**1.38**	**0.58**
Manufacturing		**0.55**	**0.55**	**0.48**	**0.60**	**0.59**
Food, beverage, tobacco	311, 312	0.59	0.64	0.53	0.39	0.28
Textile	313, 314	0.74	0.81	0.71	1.22	1.08
Apparel and leather	315, 316	0.74	0.81	0.79	1.22	0.83
Wood	321	0.70	0.66	6.45	1.01	0.48
Paper	322	0.54	0.56	0.45	0.41	0.73
Printing	323	0.53	0.57	0.13	0.07	0.06
Petroleum and coal	324	0.83	0.85	0.67	0.45	0.80
Chemical	325	0.71	0.76	0.49	0.50	0.80
Plastics and rubber	326	0.63	0.67	0.49	0.42	0.19
Non metallic	327	0.70	0.68	0.37	0.20	0.06
Primary metals	331	0.67	0.63	0.98	1.14	1.57
Fabricated metal	332	0.60	0.56	0.80	0.47	0.42
Machinery	333	0.62	0.61	0.58	0.54	0.47
Computer and electronic	334	0.90	0.93	1.35	2.85	4.35
Electrical equipment	335	0.46	0.48	0.66	0.59	0.37
Transportation equipment	336	0.40	0.35	0.20	0.25	0.35
Furniture	337	0.70	0.66	0.39	0.18	0.24
Miscellaneous manufacturing	339	0.50	0.44	0.61	0.49	0.29
Services		**0.69**	**0.72**	**0.71**	**0.47**	**0.57**
Utilities	22	0.72	0.67	4.47	8.34	9.29
Wholesale trade	41	0.54	0.58	0.35	0.35	0.31
Retail trade	45 (or 44)	0.60	0.60	0.35	0.35	0.31
Transportation, Warehousing	48-49	0.40	0.43	1.67	0.60	0.09
Information and cultural	51	0.65	0.63	0.34	0.22	0.40
FIRE, management	52, 53, 55	0.62	0.61	3.27	0.37	0.74
Professional services	54	1.12	1.10	2.05	1.07	1.23
Administrative services	56	1.12	1.10	2.26	1.01	0.57
Arts, entertainment	71	0.65	0.62	2.26	1.01	0.57
Accommodation and food	72	0.65	0.62	2.26	1.01	0.57
Other private services	81	0.65	0.62	2.26	1.01	0.57
Total Business		**0.64**	**0.68**	**0.55**	**0.56**	**0.54**

*Due to data limitations, for calculation of the share of university hours worked, the average is used for professional and administrative services as one group and for arts, entertainment, accommodation, food, and other private services as another.

**Similarly, for R&D intensity, the average is used for wholesale and retail trade as one group and for administrative services, arts, entertainment, accommodation, food and other private services as another.

Source: Authors' calculations based on data from Statistics Canada, the U.S. National Science Foundation, the U.S. Department of Agriculture, and Jorgenson (2004).

Table 5: Canada-U.S. Relative Trade Openness by Industry*

Industry	NAICS Code	Trade Openness**					
		Canada			U.S.		
		1995	2000	2003	1995	2000	2003
Primary		**1.16**	**1.18**	**1.38**	**0.87**	**0.81**	**0.86**
Agriculture	11	0.83	0.91	0.83	0.58	0.49	0.51
Mining	21	1.43	1.29	1.66	1.16	1.19	1.25
Manufacturing		**3.19**	**3.50**	**3.27**	**1.12**	**1.25**	**1.28**
Food, beverage, tobacco	311, 312	1.10	1.37	1.46	0.49	0.43	0.44
Textile	313, 314	2.72	2.94	3.04	0.65	0.93	1.20
Apparel and leather	315, 316	2.16	2.42	3.19	2.31	3.87	5.39
Wood	321	2.15	1.84	1.62	0.78	0.66	0.63
Paper	322	2.17	2.40	2.35	0.59	0.65	0.73
Printing	323	0.52	0.53	0.49	0.18	0.19	0.22
Petroleum and coal	324	4.79	4.65	4.24	1.65	1.39	1.18
Chemical	325	2.39	3.63	3.67	0.80	1.00	1.07
Plastics and rubber	326	2.20	2.42	2.32	0.44	0.54	0.58
Non metallic	327	1.66	1.89	1.27	0.41	0.51	0.46
Primary metals	331	3.22	3.01	2.85	1.11	1.40	1.44
Fabricated metal	332	2.01	1.85	1.58	0.36	0.42	0.47
Machinery	333	4.61	4.80	4.49	1.94	1.57	1.63
Computer and electronic	334	8.28	7.96	9.66	2.47	2.45	2.98
Electrical equipment	335	4.09	4.80	5.02	0.98	1.35	1.38
Transportation equipment	336	5.73	5.84	5.84	1.68	1.90	1.83
Furniture	337	1.87	2.09	1.77	0.36	0.57	0.73
Miscellaneous manufacturing	339	4.24	4.12	3.70	1.29	1.44	1.51
Total		**2.68**	**2.83**	**2.74**	**1.07**	**1.19**	**1.22**

*Data are not available for construction and service industries.

**Defined as sum of exports and imports to GDP (at factor cost) ratio.

Source: Authors' calculations based on data from Statistics Canada, Industry Canada, the U.S. BEA and the U.S. International Trade Commission.

Table 6: Panel Estimation Results (Period SUR with Panel-Corrected Standard-Errors)

Dependent Variables: Canada-U.S. Relative TFP Level (U.S.=1)[+]			
Explanatory variables	(1)	(2)	(3)
M&E capital intensity[+]	0.1317*** (0.0000)		
ICT capital intensity[+]		0.0126* (0.0633)	
Share of university hours (-1)[+]	0.0092 (0.5083)	-0.0005 (0.9745)	0.0009 (0.9496)
R&D intensity (-1)[+]	0.0029 (0.1441)	0.0072*** (0.0004)	0.0069*** (0.0008)
ICT share in M&E capital[+]	-0.0156** (0.0291)		
Openness[+]	0.0580*** (0.0000)	0.0493*** (0.0000)	0.0473*** (0.0000)
Capacity utilization[++]	1.0189*** (0.0000)	0.9992*** (0.0000)	0.9969*** (0.0000)
D_1	-0.0336 (0.6507)	-0.2182*** (0.0016)	-0.2346*** (0.0005)
D_2	0.0282 (0.8611)	0.1134 (0.4501)	-0.0701 (0.6354)
D_3	-0.0220 (0.7124)	-0.0428 (0.4465)	-0.0561 (0.3125)
D_4	-0.0957 (0.2440)	-0.1704** (0.0266)	-0.1681** (0.0271)
D_5	-0.0147 (0.8345)	-0.0132 (0.8426)	-0.0470 (0.4577)
D_6	-0.0421 (0.7137)	-0.1343 (0.2055)	-0.1641 (0.1177)
D_7	-0.0936 (0.2078)	-0.0049 (0.9437)	-0.0428 (0.5225)
D_8	-0.2186*** (0.0028)	-0.2537*** (0.0002)	-0.2513*** (0.0002)
D_9	0.1655** (0.0272)	-0.0687 (0.3131)	-0.0910 (0.1725)
Adjusted R^2	0.9125	0.9062	0.9039
Observations	656	656	656
D.W. statistics	1.9968	1.9968	1.9968

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Figures in parentheses are p-values.

[+] Denote Canada-U.S. relative values (US=1), in natural logarithm.

[++] Denote differences in Canada-U.S. values.

Source: Authors' estimates.

Table 7: Contribution of the Explanatory Variables to the Canada-U.S. TFP Gap*

	2003
M&E capital intensity	97.0%
Skills	3.2%
R&D intensity	2.2%
Business cycle effect	-13.6%
Openness	-22.4%
ICT/M&E ratio	-3.0%
Residual	36.6%

* Estimated at the sample means. The first model in Table 6 is used for the estimation.

Source: Authors' estimates.

Table 8: Panel Estimation Results (Cross-Section Weights with Panel-Corrected Standard-Errors)

Dependent Variables: Canada-U.S. Relative TFP Level (U.S.=1) +			
Explanatory variables	(1)	(2)	(3)
Intercept	0.0306*** (0.0011)	0.0143 (0.1431)	0.0128 (0.1693)
Lagged dependent variable	0.8994*** (0.0000)	0.9031*** (0.0000)	0.9032*** (0.0000)
M&E capital intensity+	0.1279*** (0.0000)		
M&E capital intensity (-1)+	-0.1086*** (0.0000)		
ICT capital intensity+		0.0161* (0.0744)	
ICT capital intensity (-1)+		-0.0138 (0.1121)	
Share of university hours+	0.0258 (0.1859)	0.0474** (0.0212)	0.0497** (0.0157)
Share of university hours (-1)+	0.0286 (0.1293)	0.0029 (0.8812)	0.0034 (0.8614)
R&D intensity+	-0.0035 (0.2284)	-0.0035 (0.2472)	-0.0028 (0.3516)
R&D intensity (-1)+	0.0011 (0.7016)	0.0001 (0.9818)	-0.0005 (0.8547)
ICT share in M&E capital+	-0.0224** (0.0194)		
ICT share in M&E capital (-1)+	0.0214** (0.0243)		
Openness+	0.0144 (0.2562)	0.0205 (0.1281)	0.0207 (0.1215)
Openness (-1)+	-0.0041 (0.7449)	-0.0101 (0.4396)	-0.0099 (0.4448)
Capacity utilization++	0.9091*** (0.0000)	0.8885*** (0.0000)	0.8884*** (0.0000)
Capacity utilization (-1)++	-0.8954*** (0.0000)	-0.9001*** (0.0000)	-0.9004*** (0.0000)
Cross-section fixed effect	YES	YES	YES
Adjusted R^2	0.9889	0.9885	0.9885
Observations	656	656	656
D.W. statistics	1.5829	1.7124	1.7167

Note: *** significant at 1% level, ** significant at 5% level, * significant at 10% level. Figures in parentheses are p-values.

+ Denote Canada-U.S. relative values (US=1), in natural logarithm.

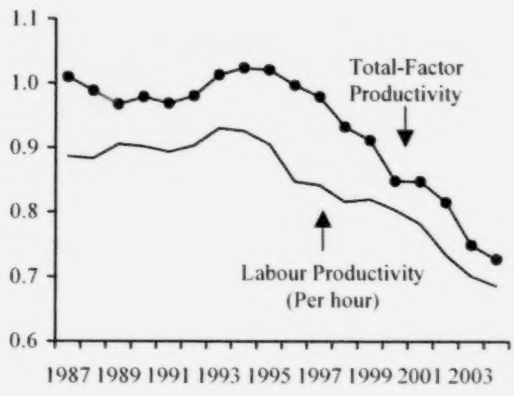
++ Denote differences in Canada-U.S. values.

Source: Authors' estimates.

Figure 1: Canada's Labour Productivity and TFP Levels Relative to the U.S., Business Sector* (U.S.=1)

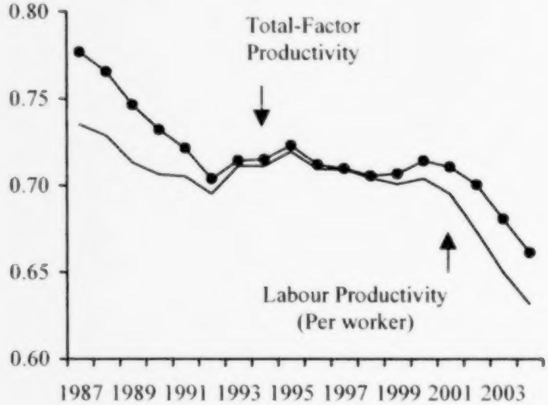
* Computed using hours worked as labour input
Source: Authors' calculations based on data from Statistics Canada, U.S. Bureau of Economic Analysis and U.S. Bureau of Labor Statistics.

Figure 2: Canada's Labour Productivity and TFP Levels Relative to the U.S., Manufacturing Sector* (U.S.=1)



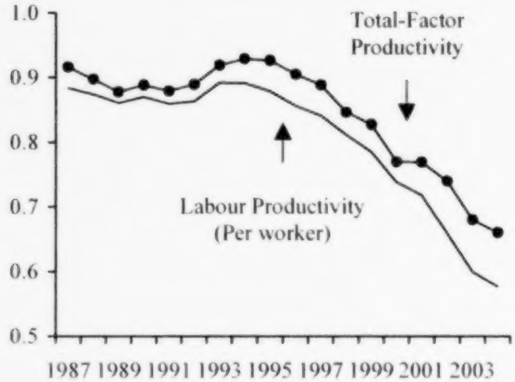
* Computed using hours as labour input
Source: Authors' calculations based on data from Statistics Canada, U.S. Bureau of Economic Analysis and U.S. Bureau of Labor Statistics.

Figure 3: Canada's Labour Productivity and TFP Levels Relative to the U.S., Business Sector* (U.S.=1)



* Computed using employees as labour input
Source: Authors' calculations based on data from Statistics Canada and the U.S. BEA.

Figure 4: Canada's Labour Productivity and TFP Levels Relative to the U.S., Manufacturing Sector* (U.S.=1)



* Computed using employees as labour input
Source: Authors' calculations based on data from Statistics Canada and the U.S. BEA.